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## Biogeographic Perspective of Macrolepidopterous Fauna from the Tomakomai Experiment Forest, Southern Hokkaido

Kunikichi YOSHIDA

Tomakomai City Museum, Suehiro 3-9-7, Tomakomai, Hokkaido, 053 Japan

**Abstract** The macrolepidopterous fauna of Hokkaido and that of the Tomakomai Experiment Forest were characterized by several comparisons on different geographic scales. In comparison on the world scale, the fauna of Hokkaido was regarded as a cool temperate type, consisting mainly of the Amur and the Siberian elements. The faunal composition in the Experiment Forest was considered to be intermediate between southern and northern extremes within Hokkaido, showing the faunal characteristics of the Ishikari Lowland.

**Key words** Macrolepidoptera, fauna, cluster analysis, biogeography.

### Introduction

Recently, INOUE *et al.* (1982) compiled the vast information on the distribution of moths within Japan. Since 1973 I have been engaged in ecological studies on the moth community in the Tomakomai Experiment Forest of Hokkaido University, and have reported several aspects of its community characteristics (YOSHIDA, 1980, 1981, 1983, 1987).

The aim of this paper is to reveal the characteristics of macrolepidopterous fauna of Tomakomai Experiment Forest on various biogeographic scales from world-wide to within Hokkaido.

### Study area and data used

The Tomakomai Experiment Forest of Hokkaido University ( $42^{\circ}40'N$ ,  $140^{\circ}31'E$ ) is located on south-eastern foothills (5 – 90 m above sea-level) of Mt. Tarumae, southern Hokkaido. The Forest (2,719 ha) is composed of natural forests (55% in area), artificial coniferous afforestations (31%), and secondary forests (9%).

The records of macrolepidopterous moths from the Tomakomai Experiment Forest were obtained by light trap collections carried out at various environments in and around the Forest during 1973 – 1985 (*cf.* YOSHIDA, 1976, 1980, 1981, 1983, 1987, for details). In addition, the records from many other areas or localities were used for comparison, based on literature. The data sources are given for each area or locality subsequently where referred to.

## Results and discussion

### 1. Faunal characteristics of Hokkaido

Table 1 shows the numbers of species of macrolepidopterous families and sub-families recorded from ten areas of the world : Borneo (HOLLOWAY, 1976); Ryukyu Islands, Amami Is., Kyushu, Shikoku, Honshu, Hokkaido (INOUE *et al.*, 1982); Great Britain (U. K.) (KLOET and HINCKS, 1972); Denmark (KARSHOLDT *et al.*, 1985); Finland (JALAVA, 1977). These papers compiled almost complete catalogues of moths in respective areas, except the data of Borneo, Amami and Ryukyu Islands where the surveys are still insufficient. The data of Borneo are based on a survey which was carried out by using light traps at thirteen sites on and near Mt. Kinabalu, Sabah, from July to September, 1965 (HOLLOWAY, 1976). Total numbers of species are large ( $>1,000$  spp.) in Hokkaido, Honshu, Shikoku and Borneo, intermediate (800 – 850 spp.) in Great Britain, Denmark and Finland, and small (400 – 600 spp.) in Amami and Ryukyu Islands. In various animals and plants it is generally known that species diversity exhibits a latitudinal gradient, increasing toward the tropics and decreasing toward the high latitudes (MACARTHUR, 1972; PIANKA, 1978). Certainly the total numbers of species in Borneo will exceed that in Japan Proper if more comprehensive surveys are made there. On the other hand, the moth fauna of Japan Proper is richer in number of species than that of Europe. The faunal make-up in all areas is characterized by two predominant families, GEOMETRIDAE and NOCTUIDAE, which occupy in combination about 70 – 80% of the total number of species.

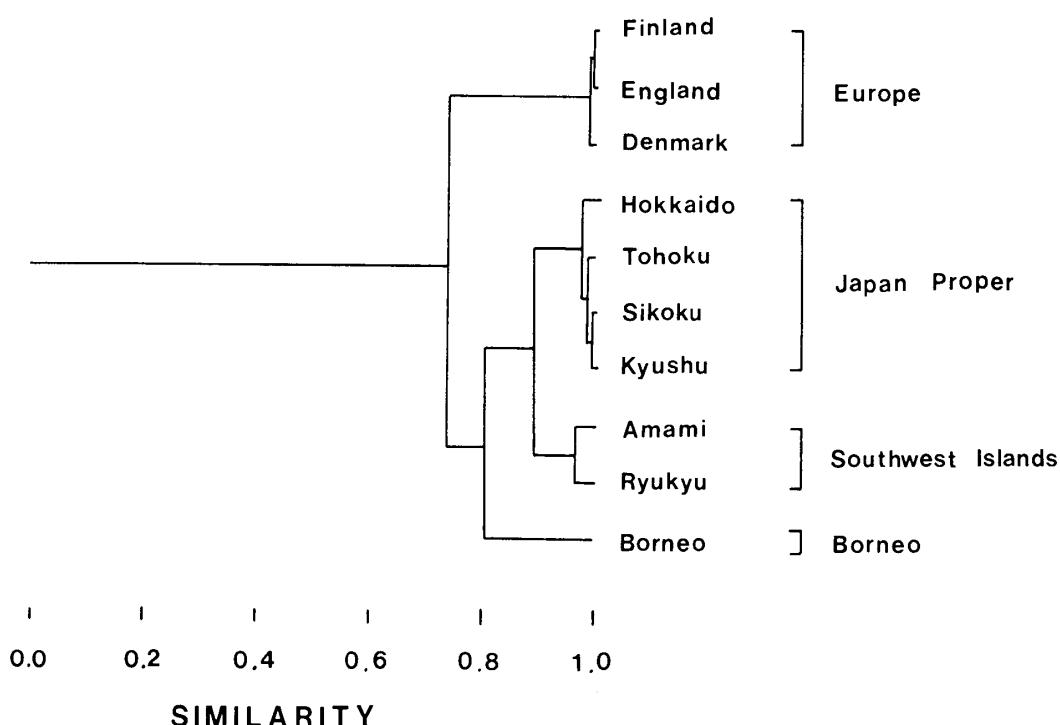


Fig. 1. Faunal similarity at family or subfamily level among ten areas.

Based on the data in Table 1, a cluster analysis (UPGMA; SNEATH & SOKAL, 1971) was made to compare faunal similarities at family or subfamily level among the ten areas. Four large families, GEOMETRIDAE, SPHINGIDAE, ARCTIIDAE and NOCTUIDAE, were subjected to the analysis at subfamily level, and the other smaller ones at family level. Families or subfamilies with less than ten species were omitted

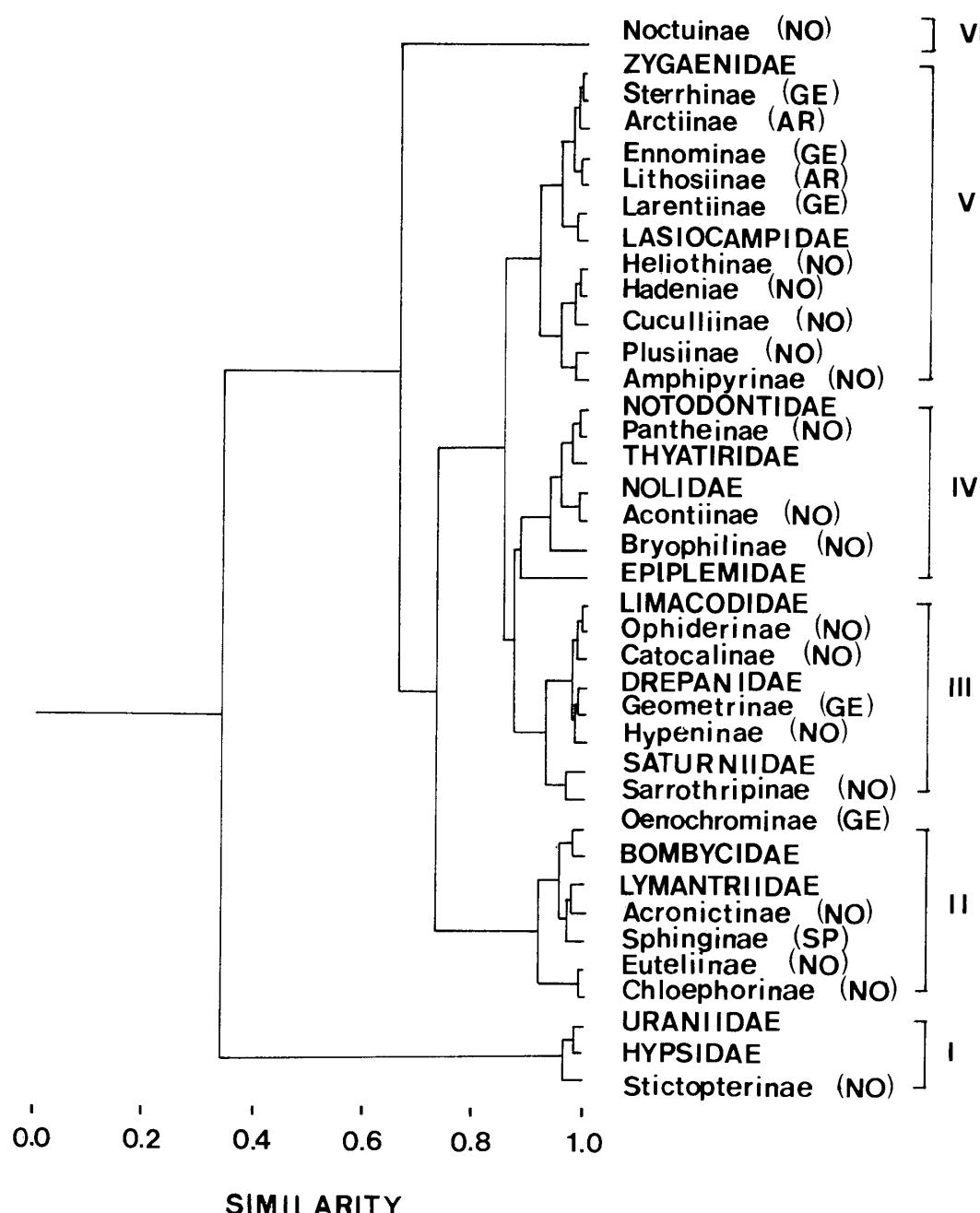


Fig. 2. Similarity of geographic distribution among 13 families and 25 subfamilies of four large families. Abbreviations of the four large families (GE : GEOMETRIDAE, SP : SPHINGIDAE, AR : ARCTIIDAE, NO : NOCTUIDAE) are shown in parentheses.

Table 1. Numbers of species (N, percent ratio in parentheses) of macrolepidopterous families or subfamilies in 10 selected areas : Finland, Denmark, Great Britain (U. K.), Hokkaido, Honshu, Shikoku, Kyushu, Amami, Ryukyu, Borneo. Families and subfamilies omitted from the cluster analyses are asterisked.

FAMILY Subfamily	Finland N(%)	Denmark N(%)	U. K. N(%)	Hokkaido N(%)	Honshu N(%)	Shikoku N(%)	Kyushu N(%)	Amami N(%)	Ryukyu N(%)	Borneo N(%)
ZYGAENIDAE	8(1.0)	8(0.9)	13(1.6)	12(1.0)	18(0.9)	13(0.8)	17(1.0)	6(1.4)	8(1.3)	15(1.1)
Phaudinae	-	-	-	1(0.1)	2(0.1)	2(0.1)	2(0.1)	-	-	-
Chalcidiinae	-	-	-	3(0.2)	6(0.3)	5(0.3)	7(0.4)	2(0.5)	7(1.2)	15(1.1)
Zyginaeinae	-	8(0.9)	13(1.6)	8(0.6)	10(0.5)	6(0.4)	8(0.4)	4(0.9)	1(0.2)	-
EPIPYRODIAE*	-	-	-	-	2(0.1)	1(0.1)	2(0.1)	-	-	-
LIMACODIDAE	1(0.1)	2(0.2)	2(0.2)	6(0.5)	17(0.8)	16(1.0)	17(1.0)	6(1.4)	9(1.5)	14(1.0)
PTEROPHORIDAE*	33(4.0)	37(4.4)	37(4.6)	17(1.4)	35(1.7)	12(0.8)	27(1.5)	6(1.4)	11(1.8)	-
Agdistinae	-	1(0.1)	1(0.1)	-	-	1(0.1)	1(0.1)	1(0.2)	2(0.3)	-
Platyptilinae	20(2.4)	22(2.6)	21(2.6)	10(0.8)	23(1.1)	6(0.4)	15(0.8)	3(0.7)	8(1.3)	-
Pterophorinae	13(1.6)	14(1.7)	15(1.9)	7(0.6)	12(0.6)	5(0.3)	11(0.6)	2(0.5)	1(0.2)	-
DREPANIDAE	4(0.5)	7(0.8)	6(0.7)	11(0.9)	24(1.2)	24(1.5)	28(1.6)	9(2.0)	7(1.2)	26(1.9)
Drepaninae	4(0.5)	7(0.8)	6(0.7)	9(0.7)	19(0.9)	19(1.2)	23(1.3)	6(1.4)	5(0.8)	21(1.5)
Oretinae	-	-	-	2(0.2)	5(0.2)	5(0.3)	5(0.3)	3(0.7)	2(0.3)	5(0.4)
CYCLIIDAE*	-	-	-	1(0.1)	3(0.1)	3(0.2)	2(0.1)	-	-	-
THYATIRIDAE	7(0.9)	9(1.1)	8(1.0)	25(2.0)	31(1.5)	23(1.5)	22(1.2)	4(0.9)	3(0.5)	3(0.2)
GEOMETRIDAE	286(34.9)	295(34.8)	291(36.1)	377(30.1)	634(30.8)	497(31.5)	536(30.1)	116(26.4)	136(22.6)	458(33.6)
Archaeinae*	2(0.2)	2(0.2)	2(0.2)	1(0.1)	2(0.1)	-	-	-	-	-
Oenochrominae	-	1(0.1)	1(0.1)	6(0.5)	12(0.6)	7(0.4)	10(0.6)	1(0.2)	4(0.7)	22(1.6)
Geometrinae	8(1.0)	9(1.1)	10(1.2)	25(2.0)	61(3.0)	53(3.4)	57(3.2)	19(4.3)	20(3.3)	72(5.3)
Sterrhinae	30(3.7)	39(4.6)	31(3.8)	35(2.8)	66(3.2)	49(3.1)	57(3.2)	21(4.7)	29(4.8)	50(3.7)
Larentiinae	171(20.9)	165(19.5)	169(20.9)	157(12.6)	241(11.7)	175(11.1)	184(10.3)	24(5.5)	30(5.0)	123(9.0)
Ennominae	75(9.1)	79(9.3)	78(9.8)	153(12.2)	252(12.2)	213(13.5)	228(12.8)	51(11.6)	53(8.8)	191(14.0)
URANIIDAE	-	-	-	1(0.1)	2(0.1)	2(0.1)	2(0.1)	1(0.2)	2(0.3)	23(1.7)
Microniinae	-	-	-	1(0.1)	2(0.1)	2(0.1)	2(0.1)	1(0.2)	2(0.3)	23(1.7)
EPICOPEIIDAE	-	-	-	1(0.1)	1(0.0)	1(0.1)	1(0.1)	-	-	-
EPIMELIIDAE*	-	-	-	5(0.4)	12(0.6)	9(0.6)	11(0.6)	7(1.6)	9(1.5)	-
Schistomitrinae	-	-	-	-	2(0.1)	1(0.1)	1(0.1)	-	-	-
Epipleminae	-	-	-	5(0.4)	10(0.5)	8(0.5)	10(0.6)	7(1.6)	9(1.5)	-
CALLIDULIDAE*	-	-	-	1(0.1)	1(0.0)	2(0.1)	2(0.1)	1(0.2)	1(0.2)	1(0.1)
LASIOCAMPIDAE*	14(1.7)	14(1.7)	11(1.4)	15(1.2)	19(0.9)	15(0.9)	17(1.0)	1(0.2)	2(0.3)	17(1.2)
EUPTEROTIDAE*	-	-	-	1(0.1)	1(0.0)	1(0.1)	1(0.1)	-	7(0.5)	-
BOMBYCIDAE	-	-	-	3(0.2)	5(0.2)	5(0.3)	5(0.3)	1(0.2)	9(0.7)	-

BRAHMAEIDAE*	-	-	-	1(0.1)	1(0.0)	1(0.1)	-	-	1(0.1)
SATURNIIDAE	2(0.2)	2(0.2)	1(0.1)	9(0.7)	9(0.4)	8(0.4)	4(0.9)	6(1.0)	5(0.4)
Saturniinae	1(0.1)	1(0.1)	1(0.1)	8(0.6)	8(0.4)	6(0.4)	4(0.9)	6(1.0)	-
Agriinae	1(0.1)	1(0.1)	-	1(0.1)	1(0.0)	1(0.1)	-	-	-
SPHINGIDAE	17(2.1)	17(2.0)	17(2.1)	35(2.8)	51(2.5)	52(3.3)	51(2.9)	26(5.2)	43(7.1)
Sphinginae	8(1.0)	7(0.8)	7(0.9)	20(1.6)	29(1.4)	25(1.6)	27(1.5)	4(0.9)	9(2.0)
Macroglossinae*	9(1.1)	10(1.2)	10(1.2)	15(1.2)	22(1.1)	27(1.7)	24(1.3)	22(5.0)	34(5.6)
NOTODONTIDAE	23(2.8)	29(3.4)	25(3.1)	77(6.1)	106(5.2)	94(6.0)	100(5.6)	8(1.8)	15(2.5)
LYMANTRIIDAE	12(1.5)	13(1.5)	11(1.4)	26(2.1)	43(2.1)	35(2.2)	39(2.2)	11(2.5)	17(2.8)
ARCTIIDAE	31(3.8)	30(3.5)	31(3.8)	51(4.1)	75(3.6)	59(3.7)	80(4.5)	24(5.5)	36(6.0)
Lithosiinae	16(2.0)	16(1.9)	16(2.0)	30(2.4)	49(2.2)	35(2.2)	50(2.8)	15(3.4)	19(3.2)
Arctiinae	15(1.8)	14(1.7)	15(1.9)	21(1.7)	28(1.4)	23(1.5)	26(1.5)	6(1.4)	11(1.8)
Nyctemeriinae*	-	-	-	-	1(0.0)	1(0.1)	4(0.2)	3(0.7)	6(1.0)
HYPSSIDAE	-	-	-	-	-	-	2(0.1)	3(0.7)	4(0.7)
NOLIDAE	5(0.6)	5(0.6)	5(0.6)	17(1.4)	32(1.6)	25(1.6)	26(1.5)	10(2.3)	9(1.5)
CTENUCHIDAE*	-	1(0.1)	-	1(0.1)	2(0.1)	2(0.1)	2(0.2)	1(0.2)	12(0.9)
NOCTUIDAE	377(46.0)	378(44.6)	349(43.2)	556(44.4)	930(45.2)	674(42.7)	779(43.7)	195(44.3)	282(46.8)
Pantheinae	3(0.4)	2(0.2)	1(0.1)	7(0.6)	8(0.4)	9(0.6)	9(0.5)	-	1(0.2)
Acronictinae	18(2.2)	18(2.1)	16(2.0)	29(2.3)	42(2.0)	26(1.6)	31(1.7)	1(0.2)	4(0.7)
Bryophilinae	-	-	-	9(0.7)	14(0.7)	11(0.7)	14(0.8)	2(0.5)	-
Heliothisinae	9(1.1)	6(0.7)	7(0.9)	6(0.5)	9(0.4)	7(0.4)	8(0.4)	1(0.2)	2(0.1)
Noctuinae	69(8.4)	66(7.8)	54(6.7)	46(3.7)	55(2.7)	24(1.5)	23(1.3)	3(0.7)	3(0.5)
Hadeninae	61(7.4)	61(7.2)	65(8.1)	55(4.4)	78(3.8)	49(3.1)	57(3.2)	12(2.7)	18(3.0)
Cuculliinae	55(6.7)	66(7.8)	57(7.1)	46(3.7)	75(3.6)	48(3.0)	49(2.7)	3(0.7)	4(0.7)
Amphipyrinae	91(11.1)	101(11.9)	91(11.3)	129(10.3)	182(8.8)	122(7.7)	137(7.7)	34(7.7)	39(6.5)
Euteliinae	-	-	-	3(0.2)	6(0.3)	5(0.3)	7(0.4)	2(0.5)	4(0.7)
Stictopterinae	-	-	-	-	2(0.1)	1(0.1)	2(0.1)	-	2(0.3)
Sarrothripinae	3(0.4)	4(0.5)	1(0.1)	7(0.6)	13(0.6)	12(0.8)	13(0.7)	4(0.9)	8(1.3)
Chioephorinae	3(0.4)	4(0.5)	3(0.4)	10(0.8)	20(1.0)	18(1.1)	22(1.2)	5(1.1)	8(1.3)
Acontinae	7(0.9)	7(0.8)	8(1.0)	40(3.2)	83(4.0)	70(4.4)	82(4.6)	24(5.5)	32(5.3)
Plusiinae	23(2.8)	19(2.2)	15(1.9)	34(2.7)	43(2.1)	25(1.6)	30(1.7)	12(2.7)	14(2.3)
Catocalinae	10(1.2)	12(1.4)	7(0.9)	26(2.1)	61(3.0)	44(2.8)	56(3.1)	23(5.2)	31(5.1)
Ophiderinae	10(1.2)	6(0.7)	10(1.2)	60(4.8)	139(6.8)	120(7.6)	141(7.9)	34(7.7)	71(11.8)
Hyperinae	15(1.8)	6(0.7)	14(1.7)	13(1.9)	37(1.8)	32(2.0)	38(2.1)	13(3.0)	16(2.7)
Herminiiinae*	-	-	-	36(2.9)	63(3.1)	51(3.2)	60(3.4)	22(5.0)	25(4.2)
AGARISTIDAE*	-	-	-	5(0.4)	6(0.3)	6(0.4)	4(0.2)	-	5(0.4)
Total	820 (100.1)	847 (99.8)	807 (99.9)	1,254 (100.0)	2,060 (99.9)	1,579 (100.0)	1,782 (100.0)	440 (100.0)	602 (100.0)
									1,361 (100.0)

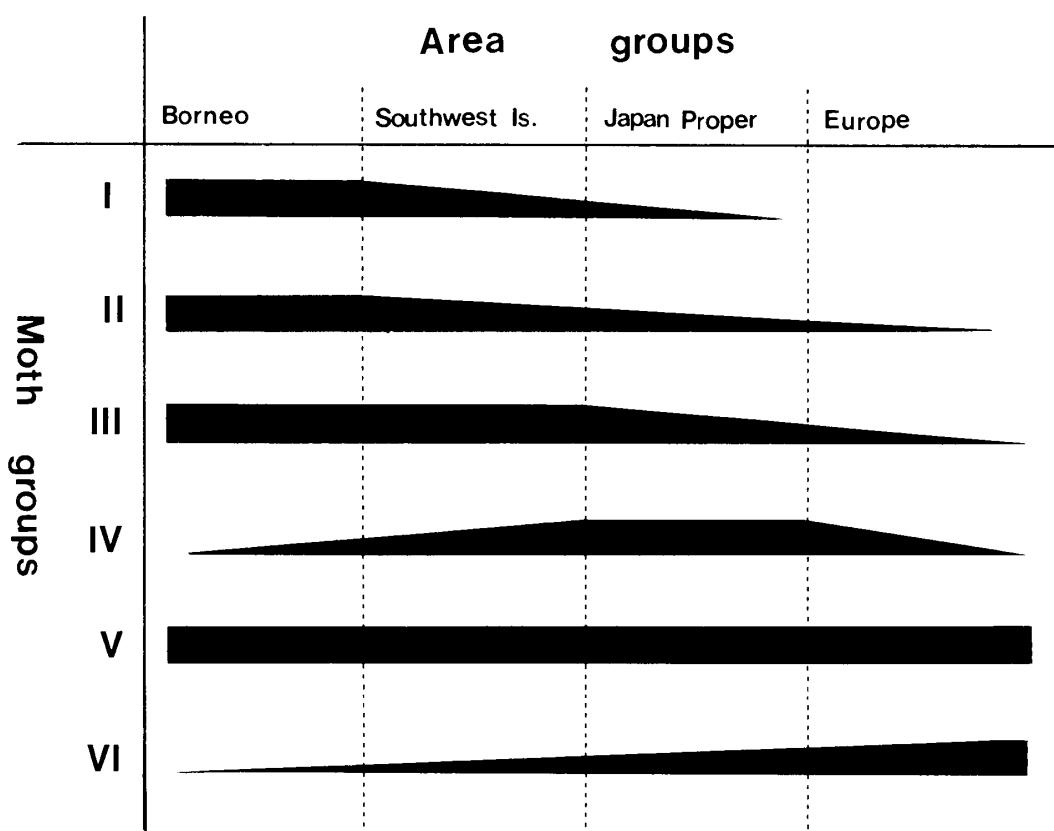


Fig. 3. Geographic patterns of six moth groups discriminated by the cluster analysis.

from the analysis. PTEROPHORIDAE and Macroglossinae including day-flying moths were also omitted, because the data for Borneo were obtained by only light traps. Consequently, the data of 13 families and 25 subfamilies were used for the analysis. The faunal similarities between all possible pairs of the ten areas were calculated by  $C\pi$  similarity index (KIMOTO, 1967). The resulting similarity matrix was subjected to the cluster analysis. From the dendrogram in Fig. 1 the ten areas were grouped into four clusters : Borneo, Southwest Islands of Japan (Amami and Ryukyu), Japan Proper (Hokkaido, Honshu, Shikoku and Kyushu), and Europe (Finland, Great Britain and Denmark).

Similarities of geographic distribution among families or subfamilies were compared by the same procedure. As a result, 13 families and 25 subfamilies were classified into six groups (Fig. 2): I (URANIIDAE, HYPSIDAE and Stictopterinae), II (BOMBYCIDAE, LYMANTRIIDAE, Oenochrominae, Acronictinae, Sphinginae, Euteliinae and Chloephorinae), III (LIMACODIDAE, DREPANIDAE, SATURNIIDAE, Ophiderinae, Catocalinae, Geometrinae, Hypeninae and Sarrothripinae), IV (NOTODONTIDAE, THYATIRIDAE, NOLIDAE, EPIPLEMIDAE, Pantheinae, Acontiinae, Bryophilinae), V (ZYGAENIDAE, LASIOCAMPIDAE, Sterrhinae, Arctiinae, Ennominae, Lithosiinae, Larentiinae, Heliothinae, Hadeninae, Cuculliinae, Plusiinae and Amphipyrinae), and VI (Noctuinae).

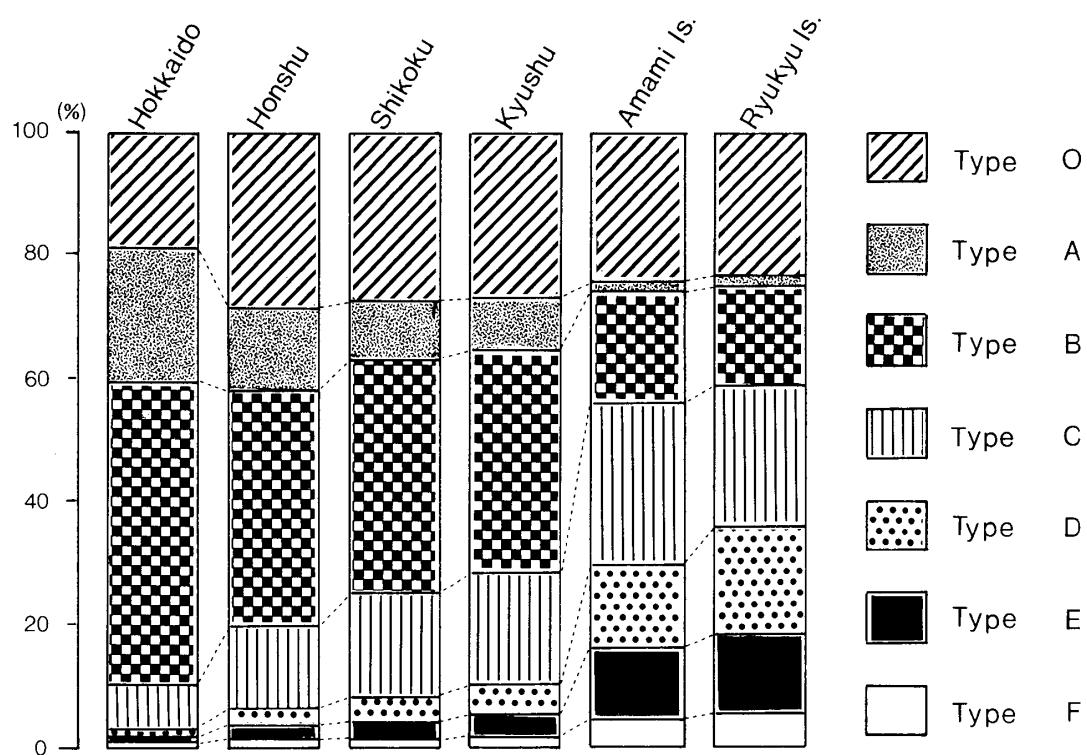


Fig. 4. Relative percentages of seven biogeographic elements of moths in six areas of Japan.

On the basis of the raw data in Table 1, the distribution patterns of six moth groups are schematically shown in Fig. 3. Groups I, II and III are predominant in Borneo or Southwest Islands, and their richness decreases gradually to the higher latitudes. Group I is absent in Europe, while Groups II and III present there. Contrarily, Group VI is predominant in Europe, and its richness decreases toward the Equator. Group IV is predominant in Japan Proper, and its richness decreases both north- and southwards. Group V occupies nearly the same percent of the total number of species in each area from Borneo to Europe. Consequently, the macrolepidopterous fauna of Hokkaido consists mainly of moths belonging to Groups IV and V.

As the next step, the fauna of Hokkaido was compared with those of other areas in Japan concerning the ratios of component species of different biogeographic elements (Fig. 4), which were classified into the following seven types according to MIYATA's (1983) system.

Type O : Species endemic to Japan.

Type A : Palaearctic species.

Type B : Species of the Manchurian subregion distributed only in the areas surrounding the Sea of Japan, e. g. China, Korea, Manchuria, Ussuri and Amur.

Type C : Species distributed mainly in the continental areas from western China to the southern side of the Himalayan Mountains.

Type D : Malaysian species mainly distributed in Indochina and the Peninsular Malaysia, further reaching Borneo, Sumatra and Java.

Type E : Indopacific species distributed wider than Type D, extending to New Guinea and Australia.

Type F : Cosmopolitan species.

Obviously percents of Palaearctic elements (Types A and B) increase northward while those of Oriental elements (Types C, D and E) increase southward. The Japanese Archipelago is regarded as located in a zone transitional between the Palaearctic and the Oriental Regions. The moth fauna of Hokkaido is mainly composed of Types A (21.9%), B (48.8%) and O (18.7%), predominantly characterized by Palaearctic elements.

## 2. Faunal characteristics of the Tomakomai Experiment Forest

Since YOSHIDA (1976) reported a list of 470 macrolepidopterous species collected from the Tomakomai Experiment Forest, more 84 species have been added to the list (YOSHIDA, unpubl.). Consequently a total of 554 species were recorded in and around the Forest in 1973 – 1985. The faunal composition of different biogeographic elements (*cf.* previous section) was compared between the Tomakomai Experiment Forest and the following 13 localities in Hokkaido (Fig. 5): Shiriuchi (KUMATA, unpubl.); Kita-

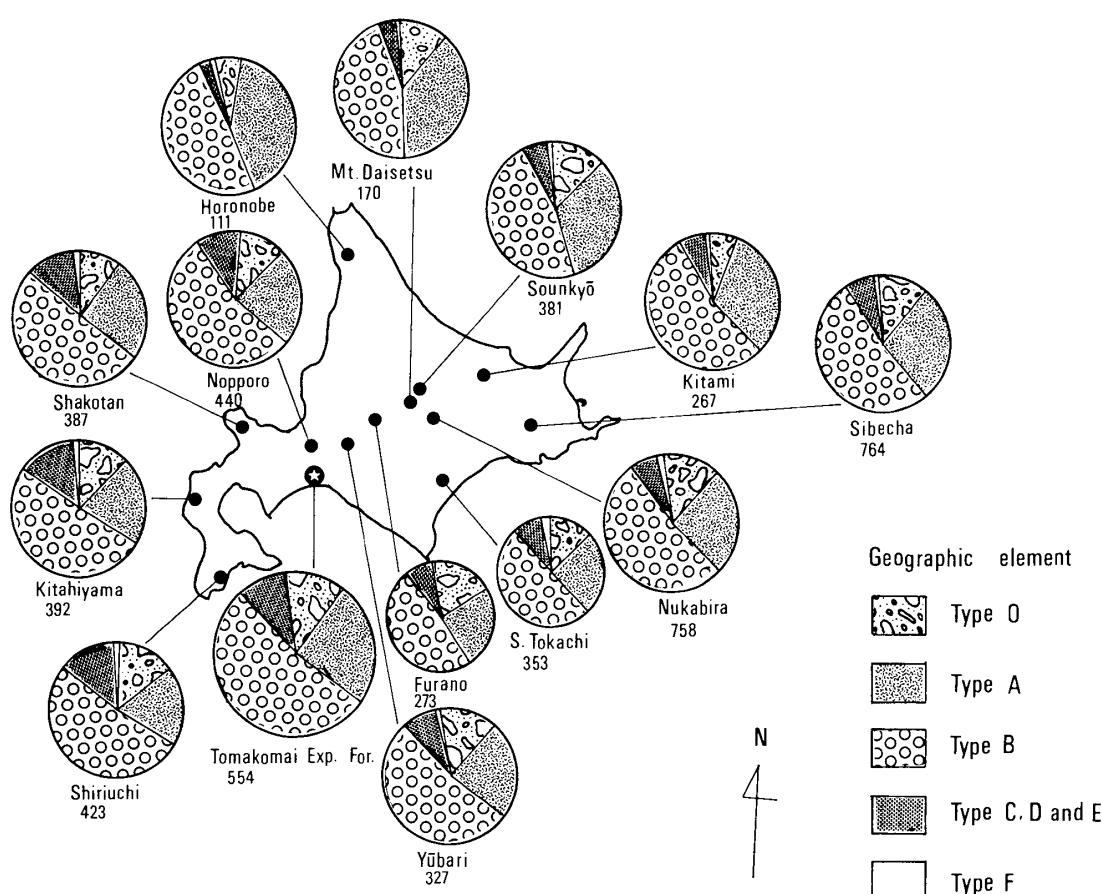


Fig. 5. Relative percentages of seven biogeographic elements in macrolepidopterous faunas of 14 localities in Hokkaido.

hiyama (YOSHIDA, unpubl.); Shakotan (KUSUNOKI, 1973, 1975, 1977, 1978); Nopporo (SAKAMOTO *et al.*, 1982); Yūbari (YAMANE and HOSHIKAWA, 1966; YAMANE *et al.*, 1968; YAMANE and TAKAHASHI, 1971; KUSUNOKI and NAKAYAMA, 1977); Furano (KUSUNOKI, 1982, 1983); southern Tokachi (KOGI, 1974a, b, 1975, 1976, 1978, 1979); Nukabira (ONO, 1967); Shibecha (IIJIMA, 1975); Kitami (YAZAKI, 1978); Sōunkyo (YASUDA, 1984; YASUDA and KUSUNOKI, 1985, 1986); Mt. Daisetsu (SUWA, 1976); Horonobe (KUMATA, 1973). The data of Furano include only GEOMETRIDAE and those of southern Tokachi only NOCTUIDAE. The clinal variation, nothward (or toward high altitudes) increase of Palaearctic elements (Type A) and southward increase of Oriental elements (Types C, D and E), is observed even within Hokkaido. The faunal composition of the Tomakomai Experiment Forest is intermediate between southern and northern extremes, and similar to that of Nopporo and Yūbari. The faunal composition of these three localities is regarded as representing the characteristics of macrolepidopterous fauna in and near the Ishikari Lowland.

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## 摘要

### 北海道南部・苦小牧演習林の蛾類相の生物地理学的特性（吉田国吉）

著者は1973-1985年、北海道大学苦小牧地方演習林において、蛾類群集の生態学的研究のため、継続的にライト・トラップ調査を実施した。これらの調査によって得られた採集記録と多くの文献により、苦小牧演習林の蛾類相を熱帯から寒帯にいたる、いろいろな地方との比較、および、北海道内各地との比較により、その特性を生物地理学的見地から検討した。

熱帯から寒帯までの10地域（ボルネオ、沖縄、奄美諸島、九州、四国、本州、北海道、イギリス、デンマーク、フィンランド）間で13科25亜科に属する蛾類をもとに、分布上の類似性につき群分析をおこなった。その結果、これらの蛾類は、6つの特徴ある分布型に類別された。北海道の蛾類相は、おもに、Group IV（シャチホコガ科など3科3亜科）とGroup V（エダシャク亜科など2科10亜科）に属する蛾類によって構成されているという地理分布的特性が明らかにされた。さらに、宮田（1983）による蛾類の分布型の類型化の方法を用いて検討した。北海道の蛾類相は、おもに旧北区のアムール系要素とシベリヤ系要素の蛾類で構成されていることが確認された。

これまでに、苦小牧演習林内およびその周辺で554種の蛾類が記録されている。これらをもとに、北海道内13ヶ所の地域（知内、北桧山、積丹、野幌、夕張、富良野、十勝南部、糠平、標茶、北見、層雲峠、大雪山、幌延）間で、宮田の方法を用いて、同様の比較、検討をおこなった。その結果、北海道内においてさえも、道北に向かって旧北区的要素の蛾類が増加し、逆に、道南に向かっては、東洋区的要素の蛾類の増加がみられた。結局、苦小牧演習林の蛾類相は、同じ石狩低地帯に位置する野幌や夕張の蛾類相とよく類似し、北海道内においては、ちょうど、南北両端の中間の傾向を示した。

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